



Aalborg Universitet

AALBORG UNIVERSITY
DENMARK

Annoyance from infrasound - alone and in combination with audio frequency noise (invited)

Møller, Henrik; Nielsen, Peter Henningsen; Andresen, Jente

Published in:

Proceedings of International Conference on Noise Control Engineering, Internoise '84, Honolulu, December 3-5, 1984

Publication date:

1984

[Link to publication from Aalborg University](#)

Citation for published version (APA):

Møller, H., Nielsen, P. H., & Andresen, J. (1984). Annoyance from infrasound - alone and in combination with audio frequency noise (invited). In *Proceedings of International Conference on Noise Control Engineering, Internoise '84, Honolulu, December 3-5, 1984* (pp. 911-916). Noise Control Foundation.

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal -

Take down policy

If you believe that this document breaches copyright please contact us at vbn@aub.aau.dk providing details, and we will remove access to the work immediately and investigate your claim.

inter-noise

Honolulu, USA
1984 December 3-5

84

ANNOYANCE FROM INFRASOUND - ALONE AND IN COMBINATION WITH AUDIO FREQUENCY NOISE

Henrik Møller, Peter Henningsen and Jente Andresen

Institute of Electronic Systems
Aalborg University
Strandvejen 19, DK-9000 Aalborg, Denmark

INTRODUCTION

For nearly 20 years researchers and environmental authorities have been worried about possible extra-auditory effects of infrasound, such as disturbance of equilibrium and influence on the circulatory system. Experimental findings are not very concordant, but in general the effects seem to have been exaggerated (1).

However, lack of direct physiological effects from infrasound does not mean that infrasound is insignificant from an environmental point of view. Infrasound can be detected by the human ear, and when it becomes sufficiently loud, it can be annoying. Some investigations indicate that a possible "threshold of annoyance" would be only slightly above the hearing threshold.

The hearing threshold at infrasonic frequencies has been determined in several experiments and also the growth of loudness above threshold has been investigated (2). Whether knowledge about the loudness of infrasound can be used in assessment of annoyance from infrasound is however uncertain and the present study was carried out.

Four experiments were included in the study. Experiment I covered annoyance from pure tones. Curves of equal annoyance were determined in the frequency range 4-31.5 Hz. Reference was made to an octave noise band at 1 kHz. In Experiment II the significance of the exposure time was investigated. Experiment III was a study of the annoyance from nonsinusoidal infrasonic noise, while Experiment IV covered annoyance from combinations of audio and infrasonic noise. The most detailed description will be given for Experiment I, while for the other experiments only changes in method will be mentioned.

EXPERIMENT I

Subjects. 18 university students aged between 20 and 25 participated as subjects. An audiometric test ensured normal hearing.

Sound conditions. Pure tones at the following frequencies and levels were used: 4 Hz: 120 and 124 dB; 8 Hz: 109, 114, 119 and 124 dB; 16 Hz: 95, 102, 109 and 116 dB; 31.5 Hz: 75, 84, 93 and 102 dB. A 1 kHz octave-filtered pink noise presented at four levels (20, 40, 60 and 80 dB) served as reference. This made a total of 18 different sound conditions.

Apparatus. The experiments were performed in a 16 cubic metre pressure chamber (3). The infrasound was emitted via 16 electrodynamic loudspeakers driven by a B & K 2712 power amplifier. The 1000 Hz noise was emitted via an equalized Hi-Fi sound reproduction system with the loudspeaker placed 140 cm from the subject. A computer controlled the experimental session.

Experimental design. Each subject was exposed to the whole range of stimuli. The order in which the subjects received the 18 stimuli was determined from a latin square design that balanced out both order and carry-over effects. Each subject was exposed to only one stimulus a day for 18 days and at the same hour every day.

Procedure. A session lasted 20 minutes during which the subjects were reading newspapers. After an initial 5 minutes period of silence the sound was presented for 15 minutes. Following this the subject was asked to indicate on a graphic scale the degree of annoyance that he would probably feel at home if his neighbour produced the same sound for two hours. The scale was a 150 mm horizontal line of which the left end was marked "not at all annoying" and the right end "very annoying".

Results. Degree of annoyance is measured in mm from the "not at all annoying" end, and the means for each sound condition are shown in Figure 1. The relationship between sound pressure level and annoyance rating is linear for the infrasonic frequencies, and regression lines are included in the figure.

In Figure 1 points of equal annoyance are represented by horizontal lines. From each of the four 1 kHz points horizontal lines have been drawn, and the points where they intersect the regression lines have been determined. These points can be shown graphically as the equal annoyance contours in Figure 2.

The equal annoyance curves demonstrate that the lower the frequency the greater the sound pressure must be to cause a given amount of annoyance. Compared with 1000 Hz the curves lie much closer in the infrasonic range. This change is already seen at 31.5 Hz, but becomes even more pronounced with decreasing frequency. The same general pattern is seen for the equal loudness curves (2), and the present results support the theory that the annoyance of infrasound is closely related to the loudness sensation.

The closeness of the curves in the infrasonic region implies that relatively small changes in sound pressure may cause large changes in annoyance. From an environmental point of view this is important since a modest reduction in sound pressure will in some cases be enough to alleviate annoyance caused by infrasonic noise.

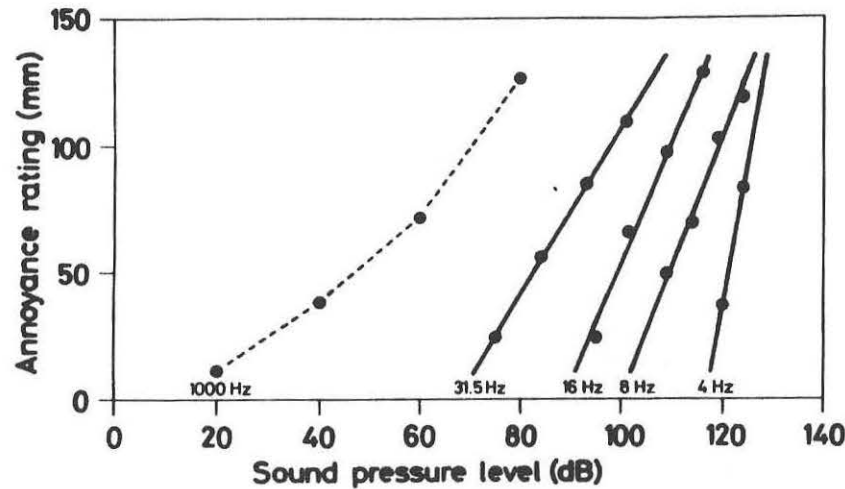


Figure 1. Annoyance ratings for pure infrasonic tones obtained in Experiment I. Filled circles represent means of 18 subjects, full lines are regression lines.

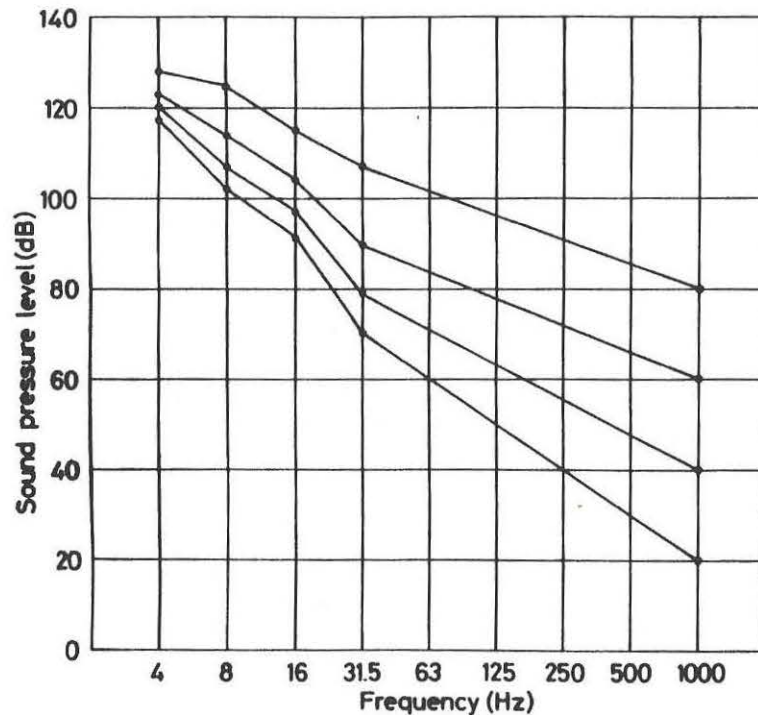


Figure 2. Equal annoyance curves for pure infrasonic tones based on results from Experiment I.

EXPERIMENT II

This experiment was carried out to show the effect of exposure time on the annoyance ratings. Subjects and exposures were the same as in Experiment I. Exposure times were

- 15 minutes preceded by 5 minutes of silence
- 3 minutes preceded by 1 minute of silence
- 30 seconds preceded by 10 seconds of silence

Results in a) were obtained from Experiment I. In b) the sound conditions were given on one day and immediately following each other. The same procedure was used in c), except that no newspapers were available because of the short exposure time.

Results. A significant effect of exposure time is seen (0.1 % level in an analysis of variance). Mean values for all sound conditions are shown in Figure 3. It is obvious that the exposure time should be specified for results obtained with the present procedure and rating scale.

There is no significant interaction between sound condition and duration. This means that although a variation with exposure time is present, this variation is the same for all sounds. Consequently, the procedure and rating scale are useful for comparative measurements, and the results will be independent of exposure time. Therefore, the use of shorter and resource saving experiments can be justified. For the two remaining experiments an exposure time of 3 minutes preceded by 1 minute of silence was chosen.

EXPERIMENT III

In this experiment the annoyance of 1/3-octave noise at infrasonic frequencies was rated. 16 sound conditions were used and consequently only 16 subjects participated. The infrasound exposure were: 8 Hz: 100, 105, 110, 115 dB; 16 Hz: 88, 97, 106 and 115 dB; 31.5 Hz: 70, 80, 90 and 100 dB. The references were as in previous experiments.

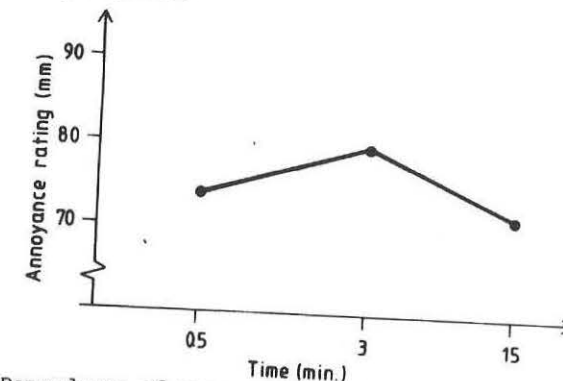


Figure 3. Dependence of annoyance rating on exposure time. The filled circles represent means of all sound conditions.

Results. The relationship between sound pressure level and annoyance rating is linear also for 1/3 octave noise. The ratings are in very close agreement with ratings for pure tones obtained for the same exposure time in Experiment II. The horizontal deviation between the regression lines are: max. 1.8 dB, mean 0.17 dB. This means that the annoyance from a pure infrasonic tone is the same as from a 1/3 octave band at the same frequency and at the same sound level. This is in contrast to what is valid at higher frequencies where normally several dB must be added to the A-weighted sound level of a pure tone in order to give a reasonable measure of annoyance.

EXPERIMENT IV

This experiment was designed to show what effect the presence of audio frequency noise has on the annoyance from infrasound. The exposures were combinations of audio frequency and infrasonic noise. The audio frequency noise was 1 kHz octave-filtered pink noise that could either be absent or appear at the three levels:

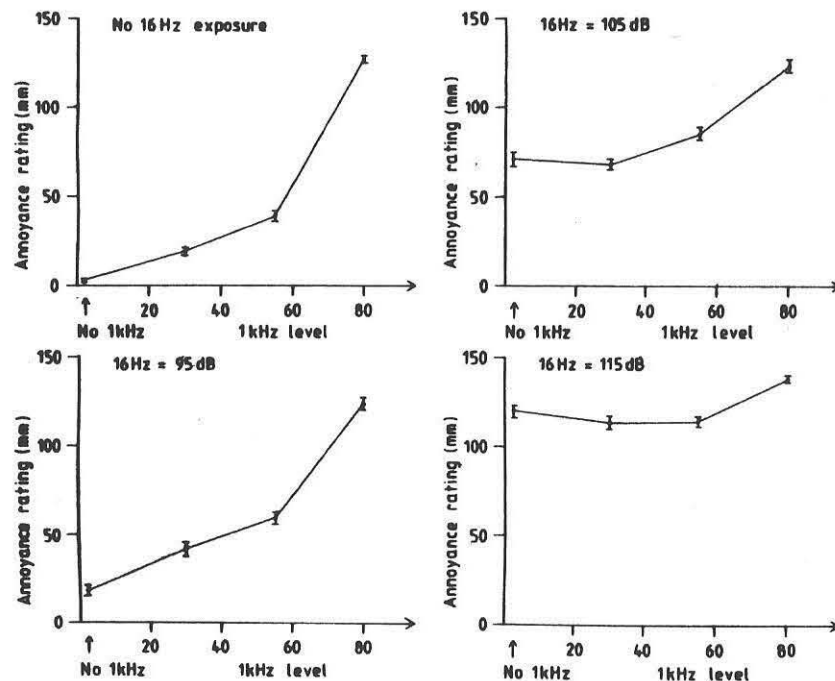


Figure 4. Annoyance ratings for combinations of audio and infrasonic noise obtained in Experiment IV. The four diagrams show results for different levels of the 16 Hz tone. The points indicate means \pm one standard error of mean.

30, 55 and 80 dB. The infrasonic noise was a pure tone at 16 Hz that could either be absent or appear at the three levels: 95, 105 and 115 dB. All combinations were used making a total of 16 different sound conditions.

Results. The annoyance ratings obtained are shown in Figure 4. Each of the four diagrams shows the results for a fixed value of 16 Hz noise. It is seen that the addition of 1 kHz noise changes the annoyance rating. All the significant changes appear as increases in annoyance. An increase is seen for all levels of the 16 Hz tone, although the needed level of 1 kHz noise is different at different levels.

A closer look at the figure will unveil that the annoyance rating of a composite noise is equal to or slightly above the annoyance rating of the most annoying of the individual noises. It is above only when the two noises are comparable in annoyance. This observation agrees well with existing experience for audio frequency noise.

The theory has been proposed that an unbalanced spectrum (a spectrum with unusually high low frequency content) should be especially annoying (4). The spectrum of pure infrasound is extremely unbalanced, and if the theory were true, the addition of audio frequency noise would reduce the annoyance. This does not happen, and the theory is not supported by our results.

SUMMARY

Contours of equal annoyance were determined for pure tones in the frequency range 4-31.5 Hz. The curves show a narrowing of the dynamic range of the ear at low frequencies. The same pattern is seen for the equal loudness curves, and the results support the theory that the annoyance of infrasound is related to the loudness sensation. Annoyance ratings of 1/3 octave noise did not deviate from ratings of pure tones with the same sound pressure level. Combinations of audio and infrasonic noise were in general given a rating close to or slightly above the rating of the most annoying of the individual noise conditions.

REFERENCES

1. Panel discussion of Conference on Low Frequency Noise and Hearing, 7-9 May 1980 in Aalborg, Denmark. Aalborg University Press, 1980.
2. Møller and Andresen: Loudness of pure tones at low and infrasonic frequencies. To be published in Journal of Low Frequency Noise and Vibration.
3. Møller: Construction of a test chamber for human infrasound exposure. Journal of Low Frequency Noise and Vibration, vol. 1, no. 3, 123-134, 1982.
4. Bryan: Low frequency noise annoyance. In W. Tempest: Infrasound and Low Frequency Vibration. Academic Press, 1976.